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HANDLE JOINTLY VIA THE
BYEMAN TALENT-KEYHOLE
CONTROL SYSTEMS ONLY

GAMBIT DORIAN RUFF

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HIGH RESOLUTION PHOTOGRAPHY

VOLUME I - TEXT

MOL Program Office

20 October, 1967

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Volume I - Text

MOL Program Office
The Pentagon
Washington, D.C.

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INDEX

NOTE: Illustrations referenced in this Volume are contained in Volume II.

DORIAN/GAMBIT/RUFF

DEPARTMENT OF THE AIR FORCE
WASHINGTON 20330

OFFICE OF THE SECRETARY

20 October 1967

PREFACE

The objective of the Manned Orbiting Laboratory (MOL) Program is to secure [redacted] resolution photography of targets significant to national security. This objective will be achieved through the development of the necessary high resolution optical technology and space flight vehicles for either manned or unmanned use.*

The manned system is being developed and will be flown first because this gives a much higher assurance of meeting the objective at the earliest reasonable date. An unmanned system is also being developed to insure a national capability to acquire very high resolution photography, in what normally are otherwise denied areas, should international objections, foreign threats, or some now unknown man-in-space physiological limitation preclude manned operations. The contributions and potential of man in a reconnaissance satellite, however, is a separate subject and is not dealt with further in this paper.

The prospect of exploiting the MOL photographic product has stimulated a continuing study by the MOL Program Office of the means by which the system may best be employed and also of the utility of photography in this resolution class. Unfortunately, real-world examples of MOL/DORIAN-type photography from the Sino-Soviet Bloc have not been plentiful in the past, [redacted] Thus, study of the problem has been dependent, for the most part, on projections forward from current requirements and experience in overhead reconnaissance to the time period of a system which will supply photographic intelligence information not now available except in isolated instances.

This paper summarizes some of the more significant results thus far of the MOL Program Office effort on the value of and need for very high resolution photography. Data and information have been accumulated through research of intelligence reports; from analysis of documents on resolution requirements published by the United States Intelligence Board and Department of Defense agencies (for example, by the Air Force Foreign Technology

*NOTE: All overhead reconnaissance aspects of the MOL system and the fact that an unmanned system is also being developed in the program is BYEMAN-Security Information under the BYEMAN code word designator DORIAN.

Division); by direct examination of current satellite, aircraft, and ground-source photography; and from informal discussions with intelligence analysts from interested organizations.

In this paper, particular attention is directed toward practical examples of the ways in which very high resolution photography -- if it were available -- could be applied toward current high-priority intelligence objectives. No inference is intended that the MOL system will contribute to answering these particular and immediate questions; however, there is good reason to believe that future problems will follow in the same pattern as new Soviet weapon systems appear and as other nations (for example, Communist China) develop intercontinental nuclear capabilities.

I. INTRODUCTION

High Resolution Photography

Early in the MOL Program Office effort, it became obvious that there was no established and accepted definition in common use for so-called "high resolution" photography. The term generally is rather loosely applied and often pertains only to the standards of a particular individual or agency, or a specific source or type of photography. It did appear, however, that many intelligence interpreters and analysts tend to define two different general classifications, each of which is meaningful in its intended context with respect to high quality photography.

One common classification is typified by the best pictures acquired from within the Sino-Soviet Bloc -- [redacted] The resolutions of those having the most utility characteristically range from about [redacted] Figure 1 is an example of [redacted] photography [redacted], with a resolution estimated at [redacted] Figure 2 is a photograph taken during a [redacted] several years ago, with slightly better resolution. Figure 3 is an example from [redacted] activities, again with a resolution in the [redacted] range. The value of this class of photograph is evidenced by the definitive drawings and performance estimates produced by analysts from the details of components and subsystems seen in the photographs and by the accurate sizing of critical parts of the item displayed. Figure 4 is a reproduction of part of a drawing made from photography like that in Figure 3. The MOL system is being developed to deliver a significant quantity of photography in this class of resolution.

The other classification of high resolution photography in common use is related directly to the products of present and near-term growth models of satellite collection systems. The range of this classification extends from the best satellite photography currently possible to that level calculated to yield a substantial increase in intelligence content. This viewpoint is expressed in USIB-D-33.16/8, a 1967 report documenting the results of a comprehensive survey of intelligence needs as related to the most important Anti-Ballistic Missile problems. The report concluded that "High-resolution photography is the only means that equipment, configuration and dimensions can be obtained with high confidence in the absence of [redacted] methods." With reference to current satellite photography, the document states, "The resolutions have not been good enough to date for adequate technical intelligence exploitation." The memorandum, dated 24 May 1967, to holders of USIB-D-33.16/8, lists the critical information needs and with reference to missiles contains this note: "Ground photography practically essential; KH-8 would have to be of less than [redacted] to be of significant value."

As a point of departure, for the purposes of this study, it appears reasonable to adopt these two classifications and to examine the way in which MOL photography will relate to them. Restated, they are:

1. The "<u>very high-resolution</u>" class of photography, similar to the results from [redacted] activities, which generally falls within a resolution range of [redacted].

2. The "high-resolution" class which includes the very best of current satellite and high-altitude aircraft capabilities, but which also will extend to slightly [redacted] level in the future. Photography in this classification can be defined as generally falling within a resolution of [redacted]

The Experience Background

For various reasons not germane to the thrust of this paper, the U.S. has become increasingly dependent upon satellite reconnaissance as the primary source of "hard intelligence" on activities of national security interest within the Sino-Soviet Bloc. With each increase in capability, there have been significant increases in the overall quality and confidence of our intelligence; and the intelligence community has been able to enter into and capitalize on important new and unanticipated areas of interest.

The initial KH-4's in 1960 produced photographic resolutions of 20-40 feet at the very best. By 1962-63, this capability had been improved to about 10 feet; and today, this search system provides best resolutions on the order of 8 feet. KH-7, the first so-called "high-resolution" surveillance system, produced about 4 foot resolution photography at the outset in 1963-64; and by 1966, when it had become a mature system, was occasionally providing photography at slightly better than two feet (average about three feet). The first KH-8, in 1966, returned a few photographs in the [redacted] resolution range, and when mature, is expected to provide some photography in the [redacted] range. (NOTE: The projected performance of satellite photographic reconnaissance systems in the 1970's is discussed later in this paper).

The relative growth in resolution capabilities of very high-altitude aircraft photographic reconnaissance systems has not been as spectacular as with the satellites; however, initial system capabilities were much higher. For example, early U-2 missions delivered some photography in the two-foot resolution class. High altitude aircraft presently operating in selected areas of the world are acquiring some pictures at 12-15 inches ground resolution, with a nominal quality approaching two feet. Figures 5 and 6 are representative examples of current high-altitude aircraft photography.

Thus, from the preceding, it is quite obvious that there is almost no real experience with the analysis of high altitude overhead photography of very high resolution taken over denied territory. However, there is considerable experience with very high resolution photography taken at ground level or from low altitudes by tactical reconnaissance aircraft. In this vein, it seems reasonable that meaningful projections can be made of the contributions which will be made by the MOL system, when available, in the collection of significant intelligence information.

It also seems quite possible that such projections of the intelligence value of MOL photography may be somewhat conservative. On the basis of past experience with increasing levels of ground resolution, the analysts have generally found that any improvement in resolution brought with it unanticipated benefits. To quote from USIB-D-41.13/30, a December 1965 document on the meaning of and need for higher resolution overhead photography, ". . . every time that resolution has improved in the past, we have discovered things that we did not even know we needed to discover. We expect, therefore, that photography with very high ground resolution will give us important information that we cannot anticipate at this time."

The Approach

Discussions with elements of the Intelligence Community involved in developing estimates have high-lighted numerous questions, the answers to some of which will or could have a profound influence on decisions affecting the national security posture of the United States, depending on the nature and reliability of the answers. Currently in the forefront are the Tallinn defensive system, Moscow ABM deployment, the performance and mission capabilities of several new aircraft, the fractional orbital bombardment system, and various others.

Several sections which follow will deal with some of these current problems as meaningful examples of postulating how photography of the MOL/DORIAN range of resolution, if it were available, could provide much of the information now missing. These specific problems have been selected because of their currency and the general understanding of their importance to national security. By the time the MOL system is operational, there is no doubt that most of these questions will have been answered. However, as current problems are solved, new ones will undoubtedly appear. Advancing technology will undoubtedly engender new and improved weapon systems in Soviet Russia. Further, one has only to look toward militant Communist China, with its expanding technological capabilities coupled with severe isolation from the Free World, to realize that the U.S. intelligence collection capability will be taxed to the utmost in the 1970's.

Just as no inference is intended that the MOL system will contribute toward solving current intelligence information collection problems, neither is any inference intended that photography alone can or will provide all of the answers. Some questions can be answered only with SIGINT information; others require a combination of overhead photography and SIGINT data; and a small portion cannot be answered by either type of information alone or in combination.

With this background in mind, the next six sections of this paper deal with a few outstanding examples of current intelligence objectives and how photography in the resolution range which will be provided by the MOL System, if it were available, could contribute toward meeting them.

[redacted]

[redacted]

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[redacted]

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[redacted]

V. NAVAL INTELLIGENCE OBJECTIVES

The threat posed by the naval forces of the U.S.S.R. and Communist China was for many years somewhat subordinate to the concern attached to the missiles, aircraft and ground forces of those countries. In the past two or three years, however, it has become quite obvious that both countries have embarked on programs designed to achieve a significant naval capability. At this time, the Soviet efforts are far more advanced, with systems entering or nearing the operational stage; however, the direction and apparent intent of the ChiCom naval development activity might ultimately be a more serious threat to our national security. This section discusses a few examples of current naval intelligence problems in relation to the role of high and very high resolution photography.

Soviet submarines equipped with cruise missiles apparently have a primary mission of countering naval task forces. National Intelligence Estimate 11-8-66, dated 20 October 1966, notes that all such submarines carry the SS-N-3 missile. Naval analysts are not able from current intelligence to construct an accurate model of the missile. One of the primary purposes of such a model would be to determine its radar cross-section characteristics in order to aid in defensive measures against the missile. The missile is small and photography in the [redacted] class will not be adequate; however, [redacted] resolution pictures at several angles would be sufficient to postulate reasonable approximations of the small external details affecting the radar reflection characteristics. NIE-11-8-66 also predicts the possibility of a successor to the SS-N-3 within the next 10 years with increased speed, range and accuracy.

Figure 48, with a resolution of about 24 inches, shows a Polaris-type submarine at Severodinsk. Photo interpreters state that they can detect missile launch tubes in the picture, but such information merely confirms the expected. From collateral high resolution photography, however, something entirely new was discovered. The missile launch tubes were measured very accurately and it was concluded that they were sized and built for a new ballistic missile, which is now the object of intensive search. Because of the size of the missile it probably cannot be definitely identified without very high resolution photography, which at the same time would also permit some estimates of its performance and operational characteristics.

The 18 September 1967 (Vol. I, Nr. 2) issue of the DIA weekly publication, Trends and Developments in Foreign Technology, Weapons and Systems, carried an analysis of the submarine shown in Figure 48 with an indirect comment on the inadequacies of presently produced resolutions in the statement that, "The entire data base on these units is derived from overhead photography and, therefore, any assessment of their capabilities must be considered as preliminary in nature." The CIA concluded, in their report Improvements in the Soviet Submarine Force (TCS-7367/67, 14 July 1967), that, "Over the next few years this expanded and more capable submarine force will tax U.S. capabilities to monitor Soviet submarine deployments and increase the problems of the U.S. antisubmarine warfare forces."

One of the critical design problems in a submarine propeller is to obtain very "quiet" performance at as high a speed as possible. There are a number of possible design variations to solve the problem. From an intelligence point of view, an accurate assessment of the quietness of enemy submarines is important. The CIA report on the Soviet submarine force (TCS-7367/67) postulates that, "Although the new SSBN probably will not be much faster than existing Soviet nuclear submarines because of its large size, it may have a new, quieter propulsion system . . ." This report goes on to say, ". . . the development of quieter submarines will impair the capability of U.S. land-based and seaborne submarine detection systems." Figure 49 shows a photograph produced by mission 4307 in which (much to the surprise of many people), the new Soviet SSBN Polaris-type submarine was seen with two propellers showing. Disappointingly, however, the resolution is so poor that design features pertinent to efficiency and quietness cannot be estimated to any acceptable degree of confidence.

Naval Intelligence Analysts believe that the critical examination of the combat equipment carried by naval task forces in photography of [redacted] resolution can reveal much about their mission (whether offensive, defensive, anti-submarine or escort, for instance.) Launchers, missile types, search radars, fire control systems, torpedo systems, reload equipment and ECM are all photographic objectives in this resolution class. Once the details of ship configurations have been established from very high resolution photography, it would be possible to identify some of them with KH-8; but without the prior basic description, many details would probably be overlooked at the poorer resolution.

VI. ARMY INTELLIGENCE OBJECTIVES

The Tallinn and ABM examples discussed earlier in this paper are characterized by their criticality to national defense planning in terms of their strategic import. The discussion that follows focuses on a different class of intelligence inquiry in which tactical and conventional war considerations are involved. Further, this section indicates how the introduction of very high resolution photography may transform much of the Army's effort that is now restricted to gross order of battle estimates to precise technical intelligence analysis.

The KH-8 system, at its mature performance level, will provide the first breakthrough to answer Army scientific and technical intelligence requirements on new weapon systems under development on in test at the various Soviet and ChiCom facilities. Photography having resolution at about the [redacted] level will provide useful information concerning ground force equipment in the sense that it can be more positively identified by generic type (i.e. tanks, trucks, AAA, field artillery, etc.). However, such equipment could still not be identified at these resolutions as to specific type of equipment (i.e. 152 mm gun-howitzer). Gross parameters will be possible for such items as tanks, assault guns, armored personnel carriers, artillery pieces, and other large pieces of military equipment. This, however, will not provide the detail necessary to accurately assess the performance and operational characteristics of the larger pieces of equipment, and will not provide any detail at all for the smaller weapons and weapon systems. Figure 50 is a good example of a target of interest to the

Army in which the NPIC analysis noted the presence of "probable" 152 mm and 57/76 mm guns and 40-round rocket launchers. Figure 51 is a similar example of ground force equipment in which a variety of types are present.

Procedures used today for producing the specific scientific and technical information of interest to the Army depend primarily on photographs [redacted] In other words, only those items the Soviets want the U.S. to see are shown, and those on which they still wish to maintain security are undoubtedly denied. In terms of time, this has usually meant that the Soviet equipment [redacted] has been in the hands of field units for several years. Nevertheless, in many instances, the [redacted] has been the first opportunity to view and photograph the equipment. It also has frequently meant that a similar but more sophisticated and newer item is already in production or well along in development. A [redacted] resolution capability in a satellite system will allow the Army to reduce this intelligence time-lag by monitoring on a periodic basis all of the ground weapon R&D, test and production facilities.

Army intelligence experts state that [redacted] resolution photography will enable mensuration, description and functional designation of such items as gun tubes, lighting devices, travel locks, radar feeds, wave guides, engine compartments, wheel or track width and size, bore evacuators, muzzle brakes, artillery trails, breech mechanisms, fin size and shape fueling locations, handling mechanisms and missile control surfaces. Detailed information on equipment components like those named is essential to the analyst to properly evaluate equipment early in its development cycle.

High resolution and very high resolution satellite photography will play an additional role in Army intelligence separate from technical intelligence considerations. In addition to knowing that the enemy has tanks, trucks, artillery, etc. opposing him, the ground force commander should also know the type of tank and artillery. This additional information indicates the type of unit and firepower opposing him. Because of the size of most objects that provide the necessary indicators, most of this information cannot be derived with a reasonable degree of confidence from photography at [redacted] or worse resolution; but it can be, for the most part, extracted from photography in the range of [redacted] ground resolution. Two target categories are described in more detail below to illustrate this point:

1. Armor. Photography at about [redacted] resolution will permit a determination that armor is present, but additional detailed information is needed for more precise order of battle information. The type of armor must be known, and to determine this, tube length and diameter, muzzle break type, mantle type and number and type of secondary armament must be identified. This information cannot be derived from [redacted] ground resolution photography, but should be on [redacted] ground-resolution photography.

2. Field and Antiaircraft Artillery. Field and antiaircraft artillery (because of its supporting role in ground combat) are generally identifiable as a generic category in [redacted] resolution photography. AAA is generally tailored to wheeled carriages identifiable by variable axle spacing; however, field artillery of different caliber often uses

the same carriage configuration. Prime examples are the Soviet 122 mm A19 Corps Gun, the 152 mm Gun-Howitzer, and the 122 mm M38 and 152 mm D1 Howitzers, all of which are of World War II vintage. More modern Soviet examples, the 122 mm D74 field gun and the 152 mm D20 gun Howitzer (mid 1950's), repeat this practice. These weapons can only be readily discriminated as to caliber by means of accurate mensuration of tube lengths and diameters, identification of breach and recoil systems, and muzzle break and fire controls. Figures 52 and 53 show the kind of detail and resolution being achieved on recent KH-8 photography. From these pictures, the nature of the problem and the requirement for much higher resolution photography are obvious.

With respect to discrimination of different types and models of artillery, the following discussion illustrates the intelligence analyst's problem. Attempts to precisely identify by model number the artillery weapons shown in Figure 50 (double arrow) were unsuccessful. The twelve weapons identified as "probable" 152 mm Gun-Howitzers were imaged in an apparent close-trail configuration with gun tubes apparently elevated to a high degree of elevation. When viewed in stereo, gun tubes could be seen (shadows can be discerned on the print). The precise point when the gun tube meets the shield could not be determined. Therefore, measurements were made of eleven of the shadows from the carriage wheels to the end of the gun tube.

Based on the shadow measurements, the average length from the center point of the carriage wheels to the end of the gun tube was calculated to be [redacted] Measurements of the apparent trails were [redacted] The trail length for both the 152 Gun-Howitzer (ML-20) and the 122 mm Corps Gun (A-19) is [redacted] and the tubes on both can be elevated to 65 degrees. All of the gun tubes of the weapons appear to be elevated substantially higher than 45 degrees.

The measurements obtained from the photograph would eliminate the 130 mm Field Gun (M-46) and the 152 mm Howitzer (M-10), since the maximum degree of elevation for the M-46 is 46 degrees with a trail length of [redacted] and the maximum tube elevation of the M-10 is 65 degrees with a trail length of only [redacted] However, the 152 mm Gun-Howitzer (ML-20) and the 122 mm Corps Gun (A-19) have exactly the same configuration. The trail design and the location of the equilibrators are identical and both have limbers. Only the end of the gun tubes are different, but this detail could not be discerned on this particular KH-8 photography. Photography in the resolution range of [redacted] is required in order to produce the detail necessary for this determination.

In summary, very high resolution photography on the order of [redacted] will enable ground force intelligence experts to conduct technical intelligence evaluations on Soviet ground force equipment without dependency [redacted]. At the same time there is a very useful role for this quality of satellite photography in refining the detail and accuracy of ground force order of battle information that is so crucial to planning by field commanders.

VII. OTHER CURRENT DEFENSE INTELLIGENCE OBJECTIVES

Interviews with analysts in the Army, Navy, Air Force and Defense Intelligence Agency have produced a sampling of the many questions which determine the objectives of our collection efforts, and which are amenable to attack by means of high-resolution photography. Some of the most important areas of intelligence interest and concern have been described in detail in the previous sections of this paper. This section briefly discusses some other typical problems.

If the Soviets were to deploy multiple independent reentry vehicle warheads, the U.S. would be faced with a serious defense problem. It is therefore of great importance to know whether or not the U.S. must counter a Soviet MIRV threat, although there is no indication so far that the Soviets have tested a warhead of this type. If they were to do so, the event would probably be detected from telemetry intercepts along the test route and near the impact area. The most important intelligence needed after such an alert would be the indication of successful completion of the development effort, and the beginning of an extensive deployment program.

It is almost certain that the external configuration of the new warhead would differ from the old ones, but perhaps only to a small extent. The shape probably would be changed slightly in order to house a new payload, and some kind of a porting or venting arrangement for propulsion exhaust probably would be visible. The solution of this problem would be to examine the old missiles in great detail by high-resolution photography, and to detect by the same means any tell-tale differences in the new missiles. It would also be of considerable benefit to relate, if possible, the new missiles to the telemetry intercepts in terms of time of launch, flight and impact. Once the new configuration was established in detail, it is very likely that KH-8 coverage would be of sufficient quality for recognizing the MIRV missiles and observing their deployment to the launch complexes.

Figure 54 is [redacted] photography of a vehicle that U.S. intelligence agencies term the OB-1 (SCRAG) and the Soviets described at the time of its display as an orbital bomber. The strategic value of a weapon system like the SCRAG is the subject of considerable controversy, although a recent RAND report (RM-5364-PR, August 1967) concludes that under certain assumptions there is logic in the capability implied in a multiple-orbit system. Telemetry intercept has confirmed that some kind of fractional-orbit device has been tested; however, this particular [redacted] object may or may not be a real missile. Very high-resolution photographs from the test areas are needed in order to confirm its configuration and to estimate the performance. As in the MIRV problem, surveillance photography subsequently could probably detect its introduction into the operational missile forces.

In a manner similar to the subjects of the preceding paragraphs, it will be important to continually watch for significant modifications to old missiles. Improvement changes might very well influence the performance of deployed missiles, and the task is to detect any program of retrofit into old silos. As an example, any retrofit of a new type guidance system could improve the accuracy of their missiles, thus directly influencing force structure considerations on both sides.

Another question of considerable importance concerns the extent to which the Soviets may convert to solid-propellant missiles. Telemetry has detected two vehicles, termed KY-6 and KY-8, in launches from Kapustin Yar. They could be test vehicles for solid propellant stages or they could be new IRBM or submarine-launched types. The configuration differences would allow a proper determination, but the missiles are small and high-quality photography on the order of [redacted] resolution will be needed to see the differences.

The operational capabilities and limitations of the Soviet (and further in the future, the Chinese Communist) ICBM forces are of extreme interest to U.S. defense planners. Such aspects as re-fire capability, reaction time, missile maintenance recycle periods, alert standby configuration and silo loading sequences could have a great influence on force structure and war plan considerations, if the cited factors were known. Figures 55, 56 and 57 show a sequence seldom seen by U.S. intelligence experts -- silo loading operations in a two-day period at one ICBM complex. The three photographs happen to be on three different silo holes, but all three are of the same kind and covered at essentially the same time. The resolution in these photographs is on the order of two feet, and their value in the sense set forth here is extremely limited. The pictures would have to be in the [redacted] category before very many significant operational details could be detected.

There are at least 20 sites in the USSR having radars thought to be associated with ABM activity, most of them apparently of unfamiliar arrangement, and some of which probably are R&D test installations. Figure 24, referenced in the earlier discussion of the Tallinn System, is a newly detected facility of this kind. Figure 58 is another example of such a new radar test area at Sary Shagan. The resolution of the picture is estimated to be about 24 inches. The antenna elements are beginning to show at this resolution, but much better quality pictures will be needed before any detailed description can be made, since this configuration does not relate to any other known model. The objective, of course, is to deduce its mode of operation and to produce clues for search and identification of Elint intercepts.

National Intelligence Estimate 11-3-66, dated 17 November 1966, cites evidence that the Soviets are investigating over-the-horizon-detection radar techniques. The report states, "We have no evidence now of an operational OHD system for detection of missiles, and we cannot tell when or even if the Soviets could develop a sufficiently reliable system to warrant deployment." There are six sites in the USSR presumed to have OHD radars. The elements of these arrays are characteristically very small and the arrangements are complex. High resolution photography will be necessary, in addition to SIGINT data, to derive an understanding of the system, to give some idea of how to pick the signal from the background noise, and especially to detect any new technological approaches.

An attractive method by which a country's strategic air capability can be materially improved is the addition of stand-off air-to-surface missiles (ASM) to the long-range bomber force. For example, the capabilities of the

U.S. B-52 fleet were enhanced by the introduction of the HOUND DOG missile. In a similar manner, Soviet long-range bombers now carry missiles like the ASM-1 KENNEL shown in Figure 59. The intelligence problem is to analyze the capabilities, effectiveness and threat implications on our defense of ASM vehicles like those shown in Figure 59. The FTD resolution requirements document cited in the New-Generation Aircraft section identifies the resolutions required for 14 individual measurements on an ASM missile that are necessary to produce an accurate technical analysis and evaluation. Of these 14 separate measurements (e.g., fuselage, wing, air inlet, radome, etc.), 12 require [redacted] photographic resolutions.

VIII. ELEMENTS OF INFORMATION

The preceding six sections have dealt with two current and pressing national intelligence objectives (Tallinn Defensive and Moscow ABM Systems), one overall category (New Generation Aircraft), and three general areas (Naval, Army, and miscellaneous Defense Objectives) with regard to the additional information which probably would be in hand were more photography in the "high" and "very high" resolution classifications available.

Perhaps, at this point, it would be helpful to deal briefly with the need for these kinds of photography in a broad statistical sense. For this purpose, some material has been extracted from a 1965 study by USIB's Committee on Overhead Reconnaissance (COMOR), which was a rather thorough analysis of the meaning of higher resolution from the Intelligence Community's point of view. Early in the COMOR effort, a review was made of the then-current elements of information on which intelligence was required -- regardless of source -- and estimates made, where appropriate, of the photographic resolutions necessary to provide the desired information.

The overall area of desired intelligence information was divided into eleven general categories (Missile R&D, Aviation, Nuclear Production, Submarines, Electronics, etc.). Each general category was further sub-divided into Essential Elements of Information (for example, type of silo, inner and outer dimensions, etc.), and the photographic ground resolutions required for identification/location and for mensuration purposes were identified. For example, under the general category of Missile Research and Development, an Element of Information for ICBM hard silos was "type", this reportedly could be identified and/or located with five-foot resolution. Another Element of Information was Silo Dimension; to measure the inner and outer diameters of ICBM-type silos required [redacted] resolution.

Approximately 850 items in the eleven categories were identified as Essential Elements of Information (EEI) along with the camera modes (stereo or mono) and photographic resolutions associated with them for identification and/or location objectives. Additionally, approximately 300 Essential Elements of Information associated with mensuration purposes were listed separately among the eleven categories along with the camera modes and required photographic resolutions.

A survey of the 850 EEIs associated only with identification and/or location indicates that approximately 22 percent required photographic resolutions of [redacted] for satisfaction; and approximately nine percent required [redacted] resolution. Likewise, approximately 39 percent of the 300 EEIs associated with mensuration required photographic resolutions of [redacted], and approximately 20 percent required [redacted] resolution.

Or, combining the two, approximately 26 percent of the more than 1150 EEIs associated with identification and/or location plus mensuration required photographic resolutions of [redacted] approximately 10 percent of the total required [redacted] resolution. It should be noted that no inference is intended in this paper that each individual EEI is of equal value with all others. These statistical comparisons are only made to provide an indication that a significant portion of the EEIs considered by the COMOR in 1965 did require very high photographic resolution to satisfy them.

Likewise, no inference is intended that the list of approximately 1150 Elements of Information was all-inclusive or that requirements would not change from time to time. The COMOR described their effort as exploring some of the critical elements that they perceived at the time. However, that effort did treat all of the general categories of required information and to a reasonable depth of detail. As an example of treatment in even more depth in a particular area, where the objective is largely technical intelligence, the AF Foreign Technology Division (see Section IV) recently listed 274 mensuration objectives in the analysis of photography of new aircraft, indicating that some 58 percent of these required [redacted] resolution.

Not too much importance should be attached to the rather precise percentages cited above. The nature and scope of requirements evolve with the passage of time, as does the ability to derive information from photography of varying resolutions. The main point is that a significant portion of strategic, tactical, and technical intelligence objectives do require "high" and "very high" resolution photography to satisfy their information needs.

IX. PERFORMANCE CHARACTERISTICS OF 1970 PHOTOGRAPHIC SATELLITES

The case presented for collecting very high resolution photography should be related now to performance estimates for the satellite systems which will be current in the early part of the next decade. Besides MOL, the KH-9 search system should be operational, and the KH-8 high resolution system will be fully mature. These complementary programs will constitute a formidable overhead collection capability operating in wide and versatile employment modes.

The resolution achieved on the film during a satellite mission varies from the design-point value in a distribution influenced primarily by the target contrast presented to the camera through widely diversified atmospheric haze conditions. Figure 60 shows the variation in resolution produced only by differences in target contrast -- all other factors being constant. A secondary factor is the slant range to the target as determined by the satellite altitude and photographic angle of obliquity. Figure 61 shows the relationship between angle of obliquity and resolution degradation. The effect of haze at oblique angles is apparent in the increased degradation of resolution as the angle of obliquity grows larger. The effect of perigee altitude on resolution is shown in Figure 62.

Although system specification resolution usually is quoted at perigee, nadir, and 2:1 contrast ratio, most of the actual photographic opportunities experience a combination of conditions that are worse, while a very small fraction of the pictures, under unusually clear conditions, will be better than specification.

Excellent references upon which to base performance predictions can be found in the detailed analyses which have been made of all of the KH-7 missions. The National Photographic Interpretation Center issues a Photographic Evaluation Report for each mission. Comprehensive analyses of all the readable photography from the majority of the KH-7 missions have been performed independently by the NPIC and by Eastman Kodak. These studies measured the ground resolutions achieved against targets in the photographic product. The effects of haze, altitude, obliquity and illumination were therefore present. Figure 63 is a smoothed plot of all the data from both sources showing the relative frequency of occurrence of the varying ground resolutions measured. Any specific area under the curve, when related to the entire area, will show the fraction of the total found to be in any given resolution range. It is apparent that the best examples from KH-7 were judged to have a resolution of approximately [redacted] while 20% of the total were better than 30 inches and 85% were better than 4 feet.

A good prediction of both KH-8 and MOL performance can be made by using KH-7 experience. Since the systems will operate in the same areas of the world at the same range of altitudes, the effects of haze, altitude, obliquity and illumination will be substantially the same. A plot similar to Figure 63 can be constructed by taking the best performance case as a starting point and applying the same relative distribution curve as the KH-7 results.

Figure 64 shows the performance range predicted in this manner for KH-8 in the 1970 period, at which time it will have reached maturity. It is estimated, therefore, that 6% of the mature KH-8 product will be [redacted]

[redacted] in resolution and 91% will be better than 24 inches. A significant improvement over KH-7 is apparent both at the best-performance level and in the quality of the total product. Virtually all of the KH-8 photography will exceed 30 inches in quality, compared to only 20% from the KH-7 missions.

Figure 65 is a similar prediction for the MOL system, based upon the present specification requirement of [redacted] ground resolution at 80 miles altitude, at nadir, and against a 2:1 contrast ratio target. Under the higher contrast conditions occasionally encountered, some pictures of [redacted] ground resolution can be expected. At the other end of the scale, a negligible number will be poorer than [redacted] in resolution.

With respect to the two general definitions of resolution set forth in Section I, the projection in Figure 65 indicates that approximately 58 percent of MOL photography will be in the "very high" classification [redacted]. Essentially all of the remainder of MOL photography will meet or better the definition of "high" resolution photography [redacted].

X DISCUSSION/SUMMARY

Early in the MOL Program Office study, it became obvious that there was no established and accepted quantitative defintion of high resolution photography. However, it appeared that many interpreters and analysts tended to define two general resolution categories, which, for the purposes of the study, were formalized as follows:

1. "Very high" resolution photography of the type obtained during [redacted] (generally in a range of [redacted]; and

2. "High" resolution photography representing the best obtainable from current and near-term satellite and high altitude aircraft systems (generally in a range of [redacted]).

It was also obvious that there is almost no real experience in the analysis of "high" resolution overhead photography taken over denied territory. However, there is considerable experience with "very high" resolution photography taken at ground level or from low altitudes. It therefore appeared reasonable that meaningful projections could be made of possible contributions by the MOL system, if it were available today, in meeting current intelligence information objectives, and thus achieve a better understanding of the MOL system potential.

The examination of various current national intelligence objectives revealed numerous critical requirements for "very high" resolution photography [redacted]. Further, a surprisingly large number of the elements comprising these required at least "high" resolution photography [redacted] to satisfy their identification and/or mensuration requirements. It was apparent that the MOL system, which will deliver more than half of its photographs in the "very high" resolution category, and essentially all photographs at [redacted] resolution, will constitute a major advancement in the national capability to collect vital intelligence information.

Although a great deal already is known on specific information which can be derived from very high resolution photography, in the past when resolution has improved we have discovered things that we did not even know we needed to discover. In that vein, it may be anticipated that the MOL class of satellite photography will provide additional important information not foreseen at this time.

Past experience with both aircraft and satellite overhead photography verifies that photography of higher resolution makes it possible to derive additional information from related photography of lesser quality. Many objects can be interpreted indirectly from photography of lesser resolution because their "signatures" (i.e. deployment patters, general dimensions, or shape characteristics) closely match analyses of higher resolution photography.

High or very high resolution photography is of considerable importance in establishing the degree of confidence in the information derived from photo interpretation. For example, it might be possible to postulate an object correctly in [redacted] two-foot ground resolution photography, but if the same object can be studied in [redacted] ground resolution photography, there is a significant increase in the confidence that the interpretation is in fact correct.

Military and/or political situation estimates frequently are qualified according to their degree of certainty. Such terms as "probable," "suspect," "confirmed," etc., are in standard usage. Occasionally, a situation arises wherein there is some urgency attached to the ability to present publicly, or in diplomatic exchanges, compelling evidence of the facts. The use of photography for such purposes is recalled from the crisis in Cuba. In that instance, it was possible to employ low-altitude aircraft to secure very high resolution photography with an attendant high confidence factor in its interpretation.

The picture in figure 66 is illustrative of a possible similar current situation. The objects in the center of this recent KH-8 (approximately 3-foot resolution) photography of an area outside Cairo, Egypt, were identified as "possible" Transporter-Erector-Launcher (TEL) equipment associated with the Soviet SS-1 medium-range ballistic missile. No conclusions could be drawn as to whether or not missiles were mounted on the TEL equipment at this resolution. A better KH-8 nadir photograph might have sufficed to confirm or deny the "possible" TEL interpretation, and probably would have enabled an estimate as to the presence or absence of the missiles themselves. However, if the objects were indeed SS-1 TEL equipment and missiles, and the U.S. had elected to take some action involving a public or intergovernmental presentation of the evidence, much higher quality photography would have been essential. The MOL system would ideally fulfill a mission of this kind.

The representative examples of current intelligence objectives discussed in this paper emphasize the importance of the continuing effort to acquire information on the expanding technology of the Soviets. As the questions of the present are answered in varying degrees of satisfaction, new questions will undoubtedly arise.

Even more important may be the task now developing for all intelligence information collection sources with regard to the status of Communist China. The evidence now available indicates that Chinese technology is progressing more rapidly than had been anticipated. The relative isolation of China places an added premium on overhead reconnaissance as a primary source of information. All of the arguments in favor of very high resolution photography as a means of meeting present urgent national intelligence objectives should apply to the surveillance of China with even more significance in the future.

APPENDIX: LIST OF ILLUSTRATIONS AND FIGURES

17. Tallinn Missile at Tallinn Launch Complex, Launch Position C-3, Mission 4308 (D107/23, X 64.9, y 9.5), 70X enlargement, 26 September 1967.

18. Simulated KH-8 picture of NIKE-HERCULES.

19. Simulated DORIAN picture of NIKE-HERCULES.

20. Tallinn Complex Engagement Radar Site, Mission 4306 (D157/17, X 84.0, y 12.2), June 1967.

21. Tallinn Engagement Radar, Mission 4306 (D157/17, X 82.4, y 10.4), 60X enlargement, June 1967.

22. FTD Drawing of the Tallinn Engagement Radar, January 1967.

23. NPIC Sketch of Tallinn Engagement Radar.

24. Possible Electronic Facility Under Construction at [redacted] USSR, Mission 4307 (D106/7, X 68.2, y 7.3), 20X enlargement, August 1967.

25. Simulated KH-7 photograph of U. S. Radar.

26. Simulated KH-8 photograph of U. S. Radar.

27. Simulated DORIAN photograph of U. S. Radar.

28. GALOSH Cannister [redacted]

29. GALOSH Cannister at Moscow ABM Complex E-24, Mission 4307 (pass D26/24, X 80.6, y 12.2) 60X enlargement, 18 August 1967.

30. Suspected Missile Components at Sary Shagan Complex B, Launch position C-3, Mission 4308 (pass D40/19, X 80.2, y 2.8), 90X enlargement, 22 September 1967.

31. GALOSH Cannister at Sary Shagan Complex B, Launch Positions 3 and 4, Mission 4031 (Pass D88/7, X 70.8, y 16.5), 70X enlargement, August 1966.

32. Moscow ABM Complex E-24, Mission 4306 (Pass D75/7, X 79.0, y 12.4), 25 June 1967.

33. Triad Radar, Moscow ABM Complex E-24, Mission 4028 (Pass 10D/28, X 62.8, y 19.3), May 1966.

34. 60-foot Triad Antenna Dish, Moscow ABM Complex E-24, Mission 4028 (Pass 10D/28, X 62.8, y 19.3), May 1966.

35. 22-foot Triad Antenna Dish, Moscow ABM Complex E-24, Mission 4306 (Pass D75/7, X 78.4, y 11.6), 20X enlargement, 25 June 1967.

36. 40X enlargement of Figure 35.

37. Mounted Triad Antenna Dishes, Moscow ABM Complex E-24, Mission 4307 (Pass D42/38, X 63.0, y 10.8), 20X enlargement, August 1967.

38. Doghouse Radar Transmitter [redacted] Mission 4028 (Pass D10/22, X 63.0, y 10.4), May 1966.

39. Doghouse Radar Receiver, [redacted] Mission 4028 (Pass D10/22, X 66.0, y 9.5), May 1966.

40. FLAGON A and B, [redacted] USSR, Mission 4306 (pass D8/14, X 73.3, y 11.2), 21 June 1967.

41. Sukhoy FLAGON [redacted] USSR, 8-9 July 1967.

42. FOXBAT Fighter, [redacted] USSR, Mission 4037 (Pass D/41/9, X 62.2, y 13.2), 40X enlargement, 25 May 1967.

43. Mikoyan FOXBAT Fighter [redacted] USSR, 8-9 July 1967.

44. Mikoyan FLOGGER Variable-Geometry Aircraft [redacted] USSR, 8-9 July 1967.

45. Unidentified Aircraft, [redacted] USSR, Mission 4306 (Pass A80/9, X 70.0, y 19.1), June 1967.

46. Unidentified ChiCom New-Generation Aircraft (Sino-A) [redacted] Mission 4308 (D86/32, X 82.4, y 15.0), 90X enlargement, September 1967.

47. FLAGON A, [redacted] USSR, Mission 4306 (Pass D8/14, X 73.8, y 10.7), 21 June 1967.

48. Nuclear (SSBN) Submarine, [redacted] USSR, Mission 4306 (Pass D11/27, X 56.5, y 12.1), June 1967.

49. SSBN Submarine, [redacted] USSR, Mission 4307 (Pass D46/25, X 53.0, y 16.8) 40X enlargement, August 1967.

50. Artillery Training Area, [redacted] USSR, Mission 4306 (Pass D64/34, X 70.0, y 7.5), 24 June 1967.

51. [redacted] Army Barracks, USSR, Mission 4307 (Pass D150/40, X 64.1, y 6.1) 20X enlargement, August 1967.

52. [redacted] Army Barracks, USSR, Mission 4307 (Pass D134/12, X 61.2, y 9.1) 40X enlargement, August 1967.

53. [redacted] Army Barracks, USSR, Mission 4307 (Pass D134/12, X 60.7, y 10.0) 40X enlargement, August 1967.

54. SCRAG Orbital Bombardment Missile (MOBS/FOBS), [redacted] 7 November 1965.

55. Type IIID Silo Loading, SS-11 Missile, [redacted] Mission 4307 (Pass D10/24, X 50.8, y 16.4) 60X enlargement, 17 August 1967.

56. Type IIID Silo Loading, SS-11 Missile, [redacted] Mission 4307 (Pass D26/28, X 49.3, y 4.0), 60X enlargement, 18 August 1967.

57. Type IIID Silo Loading, SS-11 Missile, [redacted] Mission 4307 (Pass D26/28, X 59.5, y 6.3), 60X enlargement, 18 August 1967.

58. Sary Shagan Radar R&D Site #2, Mission 4306 (Pass A14/15, X 60.7, y 7.8) 20X enlargement, June 1967.

59. KENNEL ASM, [redacted] USSR, Mission 4307 (Pass D91/28, X 53.7, y 12.6) 80X enlargement, August 1967.

60. Relationship of Contrast to Resolution.

61. Relationship of Obliquity to Resolution.

62. Relationship of Altitude to Resolution.

63. Measured KH-7 Performance.

64. Estimated Mature KH-8 Performance.

65. Estimated DORIAN Performance.

66. Suspected SCUD (SS-1) Missiles, Cairo, Egypt, Mission 4306 (Pass D139/27, X 81.4, y 19.5), June 1967.